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Hypermedia Applications for Army Installation Master Planning

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Army installation master planning involves a wide range of technical, economic, environmental, and social issues. Planning decisions are often formulated by groups whose members have varying degrees and areas of expertise, and their information is drawn from a wide variety of media. Due to the complexity of existing computer-based analytical tools, problems with information availability, and the dynamics of group decisionmaking, desirable planning alternatives may be overlooked. If key elements of a planning project do not receive adequate consideration, an installation's ability to support its mission may ultimately be impaired.

Hypermedia technology for the microcomputer offers the potential for creating a planning-support system that can enhance group communication, information availability, and the user-friendliness of analytical tools. Such a system could promote a more collaborative, comprehensive, and effective approach to installation planning than is currently feasible. This could lead to the development of better communication, more alternatives, and better planning decisions.

This report examines the applicability of hypermedia technology to planning. A prototype hypermedia system for municipal planning is discussed, and parallels between municipal and installation planning are outlined. Concepts, technologies, and system development issues are discussed, and recommendations for developing a system for the Army are offered.

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Army installation master planning involves a wide range of technical, economic, environmental, and social issues. Planning decisions are often formulated by groups whose members have varying degrees and areas of expertise, and their information is drawn from a wide variety of media. Due to the complexity of existing computer-based analytical tools, problems with information availability, and the dynamics of group decisionmaking, desirable planning alternatives may be overlooked. If key elements of a planning project do not receive adequate consideration, an installation's ability to support its mission may ultimately be impaired.

Hypermedia technology for the microcomputer offers the potential for creating a planning-support system that can enhance group communication, information availability, and the user-friendliness of analytical tools. Such a system could promote a more collaborative, comprehensive, and effective approach to installation planning than is currently feasible. This could lead to the development of better communication, more alternatives, and better planning decisions.

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FOREWORD

This research was performed for the U.S. Army Construction Engineering Research Laboratories (USACERL) under Interdepartmental Independent Research (IDIR) Work Unit CERFSM-0090-0293, "Hypermedia Planning Systems."

The work was conducted by the Facility Management Division (FF) of the Infrastructure Laboratory (FL), USACERL. The principal investigator is Bill E. Aley. Michael J. Shiffer and Mary A. Shiffer are employees of Shiffer and Associates, Inc., Arlington, MA. Alan W. Moore is Acting Chief, CECER-FF. Dr. Michael J. O'Connor is Chief, CECER-FL. The USACERL technical editor was Gordon L. Cohen, Information Management Office.

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1 INTRODUCTION

Background

The quality of Army installation planning depends on the amount of relevant information used during the analysis of problems, the development and evaluation of alternatives, and the making of decisions. Relevant information may appear in the form of forecasts, analyses, models, documents, visual images, and personal observations. This may be combined with other forms of information, such as the synthesis of the practical experience of many people into a base of information that Army installation planners must consider to make the best possible decisions.

Important sources of planning information are found in a variety of media and formats. Generally, forecasts, analyses, and models present quantitative information as manageable (understandable) packages with the aid of microcomputer technology. Documents and visual images may be provided in both printed and electronic forms. Personal observations and practical experience are frequently delivered as interpersonal communication. The components of this information transfer, then, are technological tools, units of information, and modes of communication.

Until recently, it has been difficult to integrate tools, information, and communication into a collaborative planning process. Typically one of these three elements has dominated at the expense of the others. Furthermore, due to the complexity of existing computer-based analytical tools, problems with information availability, and the dynamics of group decisionmaking, desirable planning alternatives may be overlooked. If key elements of a planning project do not receive adequate consideration, an installation's ability to support its mission may ultimately be hampered. Actions may be taken on the basis of "on-the-fly" decisions rather than well thought out planning alternatives. However, a relatively recent development in microcomputer technology--hypermedia--is for the first time making it possible to integrate all components of the planning process into an advanced decision-support tool. Such a tool could substantially improve the effectiveness of installation planning by improving the collaborative efforts that generate the decisions.

Objective

The overall objective of this research is to develop and implement for microcomputers a powerful, effective hypermedia-assisted tool for use in Army installation master planning. The purpose of this phase of the research was to investigate the applicability of hypermedia technology to the planning profession in general, study a hypermedia system develolped for municipal planning to identify concepts and requirements pertinent to Army planners, and offer recommendations for developing a hypermedia system for installation master planning.

Approach

The authors divided this phase of the research into three task areas:

1. Analyzing processes common to the planning profession in general, and identifying hypermedia methods that have been (or could be) applied to improve these processes

2. Identifying state-of-the-art hardware and software technologies that could be configured into appropriate hypermedia "brainstorming systems" for planners

3. Recommending components and concepts that should be incorporated into a hypermedia-assisted planning system for use at the Army installation level.

In the first two task areas the research drew on the experience and expertise of Shiffer and Associates, a private-sector systems developer located in Arlington, MA. The known sources of hypermedia expertise were evaluated, and this firm was selected because it had previously developed a prototype system for St. Louis, MO, municipal planners, and was considered a valuable source of lessons learned in developing recommendations for a system to meet the specific needs of Army installation planners.

Scope

This report focuses on hypermedia applications for microcomputers; hypermedia applications for mainframe computing environments are not addressed. Hypermedia-assisted planning systems like those discussed in this report could be developed for either IBM compatible personal computers or Apple Macintosh systems. Configurations for both platforms are discussed briefly for technical perspective, but the current phase of this research was concerned primarily with hypermedia concepts and characteristics that apply to *all* platforms. Specific hardware and software configurations for either platform (or both) are most appropriately addressed in a later phase of the work.

2 THE PLANNING PROCESS AND RELEVANT TECHNOLOGICAL TRENDS

Framework for a Collaborative Planning Process

The abilities to communicate, access information, and use tools effectively are central to the planning process, but planners often face the paradox of relying on one of these activities at the expense of the others. Communication often dominates in collaborative meeting environments at the expense of access to information and analytical tools. Access to information is often mastered at the expense of being able to simultaneously collaborate with a working group. Similarly, the mastery of analytical tools is often incompatible with collaborative effort because (1) planning tools may be oriented toward individual elements of a planning problem, (2) individuals who use planning tools may have biases and provide unsuitable input to collaborative planning, or (3) existing tool interfaces may be designed for individual users, not groups with diverse concerns. Hypermedia-based systems may overcome this paradox, however, so communication, information access, and the use of decision-aiding tools can be optimized in a collaborative planning environment.

To integrate these three key aspects of the planning process—information, tools, and communication—a hypermedia planning system must (1) be able to access large amounts of relevant information from a variety of media, and capabe of presenting it in a variety of contexts, (2) provide tools that can be used by personnel who may not be technically adept, and (3) simultaneously promote a working environment that encourages group interaction and communication.

Information

Planners are bombarded with a rapidly expanding information base that does not lend itself to effective organization. An effective information system is more than the contents of information files: it encompasses the whole systematic approach to obtaining, storing, retrieving, and presenting data in response to specific information needs. For the contents of an information system to be understandable, effective presentation features are essential. "The capacity to conceive and present visually attractive outputs with compelling simplicity...is an important feature. [If this link in the information provision chain is weak] the most sophisticated system is for naught."[1]

Problems in handling information are rarely caused by a lack of data but rather by its overabundance.[2] Today, planners are bombarded with a rapidly expanding information base symptomatic of the "information glut" that society in general has been experiencing.[3] This information glut is presented in a variety of different forms: statistical data from numerous sources, slides and video images of various locations, maps, documents, and minutes from past briefings. Attempts to organize this information usually only occur within a particular medium. For example, video images tend to be stored on videotape; documents are frequently stored in computer text files; and statistical data are organized into databases or spreadsheets. Until recently, however, there has been no way to access these three types of information through a single source.

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[1] F.S. Chapin and E.J. Kaiser, *Urban Land Use Planning* (University of Illinois Press, 1979).

[2] D.D. Woods, "Paradigms for Intelligent Decision Support," *Intelligent Decision Support in Process Environments*, E. Hollnagel, G., Mancini, and D.D. Woods, eds. (Springer-Verlag, 1986), pp 153-173.

[3] K. Parsaye, M. Chignell, S. Khoshafian, and H. Wong, *Intelligent Database: Object-Oriented, Deductive Hypermedia Technologies* (Wiley, 1989).

Even attempts at successful organization within a particular medium have often failed because some media do not easily lend themselves to reorganization and updating. For example, in exploring alternative methods for video organization, Mackay and Davenport noted that while

> video has become an increasingly prevalent form of data for social scientists and other researchers, requiring both quantitative and qualitative analysis...the requirements researchers place upon video editing go far beyond the capabilities of traditional analog editing equipment. [These may include the abilities to] flexibly annotate video and re-display video segments on the fly [as well as a] need to synchronize video with other kinds of data.[4]

The synchronization of video with other types of data, such as text and statistics, represents an attempt to organize information across media. While the organization of information across media is still rare, there have recently been a number of successful implementations of it. For example, many geographic information systems (GISs) possess the ability to combine statistical data, maps, and several analytical models. These resulting systems have become quite useful for dealing with geography-oriented questions where there is a need for detailed statistical information about specific sites.[5] However, these attempts at information organization have rarely spanned more than two or three media due to technological constraints. Thus, the visualization of a particular site's characteristics can be difficult for those who may be unfamiliar with that area if it is displayed using a single medium such as a map.

Another obstacle encountered when attempting to organize information across several media (as well as within one medium) is the difficulty of creating a solid organizational structure while maintaining the full network of interrelationships and themes that underlie the information.[6] For example, if a television news clip is related to an earlier news clip as well as several geographic regions and documents, it is difficult to impose a hierarchical or relational structure using standard database methods without arbitrarily breaking the information into isolated records. In doing so, some of the underlying data interrelationships may be obscured. Thus, a need exists to organize information while preserving the full set of interrelationships and continuity within the data.

Communication

Many forms of communication are used in the planning environment. They range from passive communication, such as writing or reading reports, to active communication, such as participating in briefings or collaborative working sessions with colleagues. The most important form of communication in the planning environment is active communication of the type that takes place at meetings.

Meetings may range from informal working sessions of a few people to formal presentations or briefings including 100 or more participants. The open exchange of dissimilar ideas is identified as a benefit of group collaboration and interaction in planning.[7] The different criteria people bring to planning meetings need to be made explicit, interpreted, and entered into the information base so all participants can communicate effectively. In applying Habermas's critical communications theory of society to

[4] W.E. Mackay and G. Davenport, "Virtual Video Editing in Interactive Multimedia Applications," *Communications of the ACM*, Vol 32, No. 7 (1989), pp 802-810.

[5] B. Harris, "Beyond Geographic Information Systems," *Journal of the American Planning Association*, Winter (1989), pp 85-90.

[6] K. Parsaye et al.

[7] J. Forester, "Critical Theory and Planning Practice," *Journal of the American Planning Association*, July (1980), pp 275-286.

planning practice,[8] Forester suggested broadening the understanding of the planner's action from technical to communicative:

> Problems will be solved not by one expert, but by pooling expertise and non-professional contributions as well; not by formal procedure alone, but by informal consultation and involvement; not predominantly by strict reliance on data bases, but by careful use of trusted "resources," "contacts," "friends"; not through formally rational management procedures, but by internal politics and the development of a working consensus; not by solving an engineering equation, but by complementing technical performance with political sophistication, support-building, liaison work, and, finally, intuition and luck....[Planners should] develop skills to work with groups and conflict situations, rather than expecting progress to stem mainly from isolated technical work.[9]

This points to the necessity of treating planning as a social, communicative process that occurs in a group environment. It also urges the inclusion of intangibles, such as heuristics or "rules of thumb," with more tangible models and chunks of data. People must be prepared to learn from each other when responding to complex decision problems. They should recognize that there may be a variety of complementary sources of insight and experience from which to draw.[10] This position was echoed by Doyle and Straus when they asserted that

> [Performing in isolation] is generally not how society...gather[s] information for making recommendations to solve issues.... If the best solution is to be adopted, a reliance upon a team effort [through a continual interaction process] may be required as the complexities of both the business and social environment come into play.[11]

There is evidence from psychological research to support these claims. For example, the benefits of group interaction were illustrated by Sniezek and Henry in their findings that group judgments are more accurate than those of individuals especially when there is a high level of initial disagreement within the group.[12] They also found that group judgments are made more confidently than those of individuals.

Another example of the benefits of group collaboration can be found with an examination of the "spreading activation" theory of cognitive processing.[13] This theory presumes that information is stored in the brain as a group of interrelated nodes. Each node or group is linked by association. A graphic representation of this theory is illustrated in Figure 1.

In Figure 1, person X's cognitive network (represented by the black lines and ovals) consists of two distinct clusters of nodes. For example, the left cluster of nodes can consist of thoughts on how to make more money, and the right cluster of nodes can consist of thoughts related to person X's feelings of hunger. Thus, while exploring the idea of how to make more money X may jump from node A to B to C, or from "rob a bank" to "invest in stocks" to "sell Tupperware®." The real answer to the problem might lie at node E, "start a pizza delivery service." When person Y is introduced to the problem (represented by the gray lines and ovals) new connections can be drawn between nodes B and D, or from "sell Tupperware" to "hold a spaghetti dinner." This may prompt person A to settle on node E, "pizza

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[8] J. Habermas, *Communication and the Evolution of Society* (Beacon Press, 1979).
[9] J. Forester.
[10] J. Friend and A. Hickling, *Planning Under Pressure* (Pergamon, 1987).
[11] M. Doyle and D. Straus, *How to Make Meetings Work* (Wyden Books, 1976).
[12] J. Sniezek and R. Henry, "Accuracy and Confidence in Group Judgment," *Organizational Behavior and Human Processes*, Vol 43 (1989), pp 1-28.
[13] A.M. Collins and E.F. Loftus, "A Spreading-Activation Theory of Semantic Processing," *Psychological Review*, Vol 82 (1975), pp 407-428.

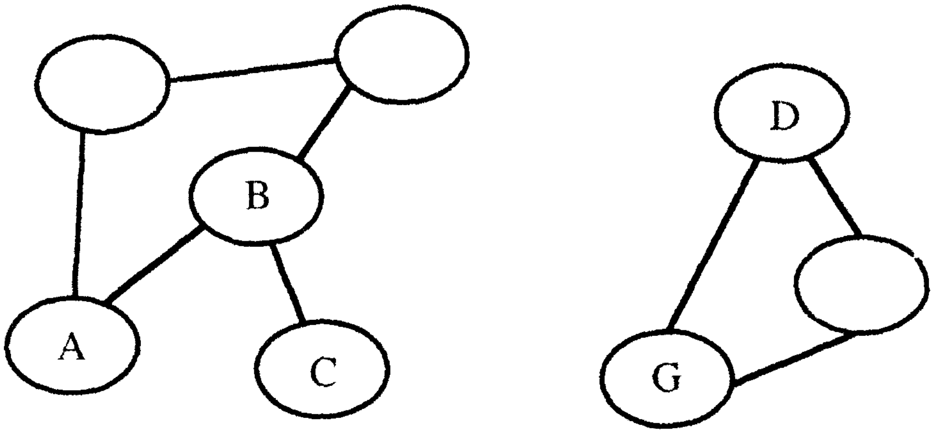

Figure 1a. Person X's thoughts on how to make money (left cluster) and feelings of hunger (right cluster).

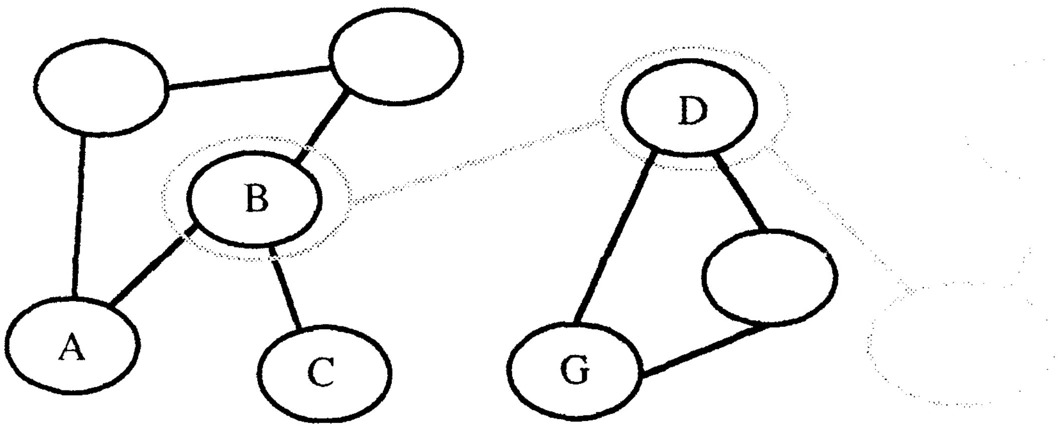

Figure 1b. Person Y is introduced to the problem and makes a new connection between nodes B and D.

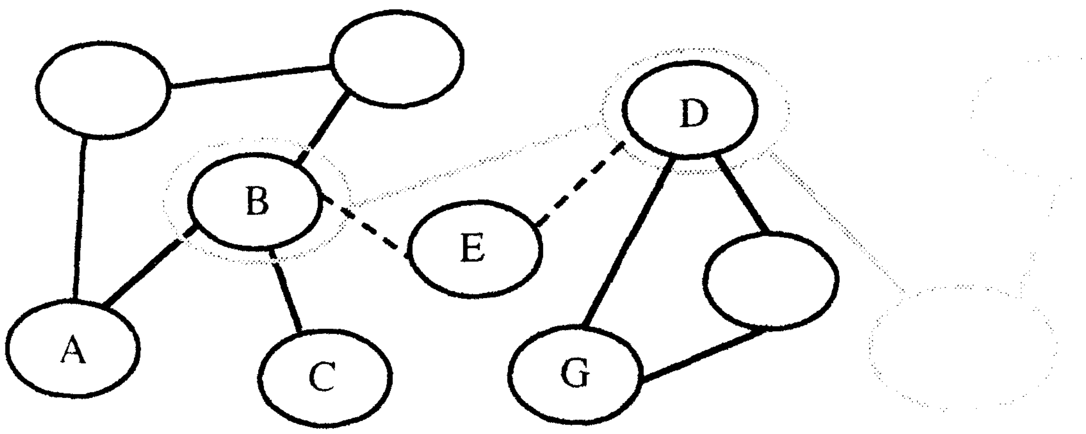

Figure 1. Illustration of the Spreading Activation Theory.

delivery," as a viable solution. Thus by "spreading activation," persons A and B are able to solve a problem that neither could have accomplished alone by merging their respective cognitive networks.

An example of clustering thoughts and comparative interface between individuals is illustrated in the context of the following story, as told from the points of view of three participants: Ann, Bill, and Chris.

Ann, Bill, and Chris are attending a planning meeting to locate a new city park. Each of them prefers to locate the park on a choice piece of land downtown along the city's lakefront. That option however, is prevented by budget constraints. A few days before the meeting while jogging, Ann passed an old factory on the lakefront and thought of what a nice site it would make to reuse the area as a recreation area. However, she rationalized that the site would probably be unattainable due to the presence of the factory and the potential high cost of acquiring the land. At the meeting, Bill laments the fact that the only viable alternative for the city's park is an inland tract of land owned by the city adjacent to a large industrial district. Chris is concerned about the high unemployment rate near the industrial area and fears that the park will do little to improve the neighborhood. Ann, Bill, and Chris attend the meeting with low expectations.

During the meeting Bill reluctantly proposes the inland tract of land as the only viable alternative. Towards the end of the meeting, Ann remembers the factory she passed and mentions how nice it would have been to be able to locate the park at the lakefront site. Unaware of the site's desirability, Chris presses Ann for more information and suggests they explore the possibility of relocating the factory to the city's inland property.

They contact the factory owner, and discover that he had wanted to modernize the facility but was prevented by the space constraints of the factory's current lakefront location. The owner welcomed relocation as a chance to modernize the factory and agreed to sell the lakefront property at a nominal fee in exchange for the city's inland property.

This example illustrates the way different people bring different criteria to planning meetings. These criteria need to be made explicit and interpreted so all participants can communicate effectively. Furthermore, access to information fosters communication by allowing participants to make the information bases they are working from explicit, and tools aid communication by allowing one to analyze or visualize the outcome(s) of several scenarios.

Tools

The ability to communicate is central to the process of planning. An information system is of little use if the relevant items pertaining to a problem cannot be communicated to, and among, a group. Even the most sophisticated analytical tools are rendered useless when individuals do not understand when or where a problem warrants the use of a tool, or how a tool should be applied. Analytical tools are of little use if their results, or the underlying assumptions about their operation, cannot be understood by the individuals involved in the planning process.

The difficulties encountered in mastering the application of analytical tools often causes less technically oriented people to be excluded from the planning process. According to Klosterman, "Control over centralized information systems tends to increase the power of administrators, technical experts, and

technically sophisticated groups at the expense of those who lack the expertise to use them effectively."[14] As this happens, technicians often become so heavily relied upon that they become "black boxes" themselves. An example of this is the use of an expert hired to provide scientific information supporting a particular point of view without regard for the methods he or she used to reach the conclusion. Thus, when a problem is fed to a technician, the decisionmakers may not understand how the answer was derived. Furthermore, a heavy reliance upon key individuals for the implementation of planning-oriented tools can result in a potentially dangerous dependence upon individuals who may be sorely missed during temporary or permanent absence. At Army installations close attention to this detail is necessary because of the high turnover rate of planning technical personnel.

Flexibility and ease of use have often been identified as important attributes of planning decision support systems. Friend and Hickling argued for the notion of an "open technology" in the decisionmaking process intended "to be freely accessible to participants who have differing and complementary contributions to make."[15] Harris also highlighted the notion that a decision support technology should be flexible when he wrote of the next logical step after GISs in planning support systems. He suggested that the planning system of the future "must be fully integrated and user-friendly, but with many options available to the planner." The use of these systems will become widespread, he said, when their capabilities are made available "in a flexible and well-designed software package that bypasses the need for high-level computer skills in the user."[16]

Thus a need exists to make analytical tools and their outputs more visually (or audibly) appealing so that information that would normally be meaningless and intimidating to the lay person can be made understandable. The benefits of this graphic display of information are supported by the experimental performance and memory evaluations on the relative value of pictures and text in conveying information by Fisk, Scerbo, and Kobylak. Their study found that pictures are generally preferable to textual instructions where performance speed is important.[17] This emphasis on the use of graphics to enhance the usability of analytical tools can be applied to collaborative planning meetings where there is little time to read and absorb text.

Relevant Technological Trends

The three components of a collaborative planning process identified in the previous section as communication, access to information, and access to tools can be respectively addressed by reviewing previous work and advances in computer-supported collaborative work, information usage, and user interface design. Recent advances and technological impacts in these fields can be used to integrate tools, information, and communication into a cohesive planning process. The parallel between planning components and recent advances in technology is illustrated in Figure 2.

Data Organization and Hypermedia

A trend that complements the idea of integrating information and tools in planning meetings has been the movement towards associative forms of information organization. These forms of information

[14] R.E. Klosterman, "Guidelines for Future Computer-Aided Planning Models," *Proceedings of the Annual Conference of the Urban and Regional Information Systems Association*, Vol 4 (1987).

[15] J. Friend and A. Hickling, p 82.

[16] B. Harris.

[17] A. Fisk, M. Scerbo, and R. Kobylak, "Relative Value of Pictures and Text in Conveying Information: Performance and Memory Evaluations," *Proceedings of the Human Factors Society 30th Annual Meeting* (1986), pp 1269-1272.

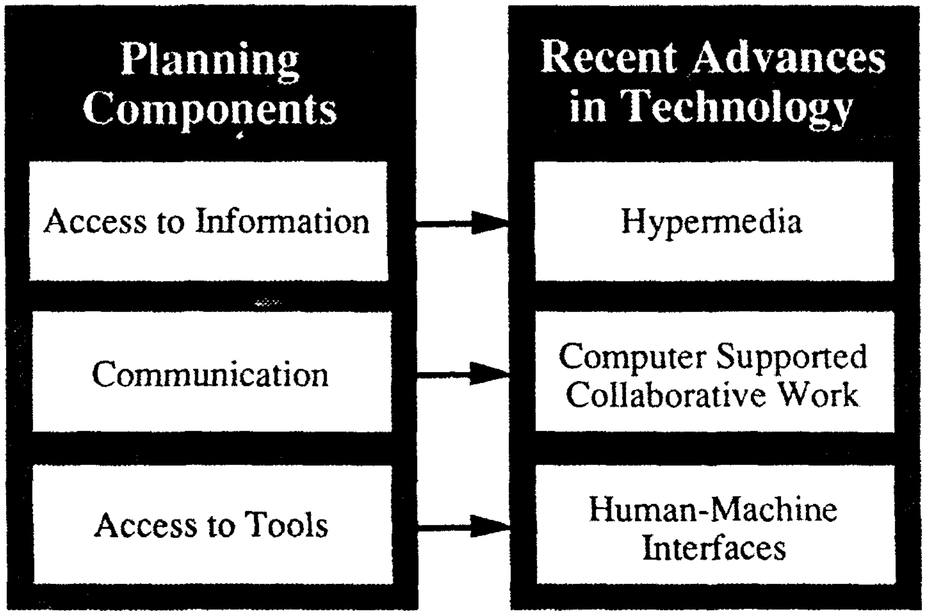

Figure 2. Recent Advances in Technology and Analogous Components of a Collaborative Planning Process.

organization ease access to information by taking advantage of the human ability to organize information in an associative manner.

Planners typically associate with geographic, textual, and visual information. Specific geographic information is most often accessed by consulting maps. For example, in a collaborative planning environment, meetings often begin by spreading a map out on a table. In this manner planners can discuss various issues in a spatial context. During this process, meeting participants often attempt to visualize the physical characteristics of a particular area. This may take the form of one or more participants attempting to recall the characteristics of a particular location and describe it to others unfamiliar with the site. This visual inspection may be aided through the use of slides, photos, videotape or a site visit. After initial familiarization with the area of concern, background information (often in the form of descriptive text from various reports, past plans, and other types of studies) are consulted. This usually occurs outside the collaborative environment for synthesis into future meetings. This is particularly true for the Army installation planner, who gathers supporting installation data from the myriad of systems available. Once this information is gathered, a series of planning meetings may be necessary to review and assimilate the new information.

This order of information access is not the only way information is consulted. Sometimes background issues presented in a textual form will precede site visits and location-based discussions. At other times, issues become apparent only upon visual inspection of a site, which may make it necessary to gather additional textual information.

There is currently a trend toward organizing information from a variety of media in a manner independent of sequence.[18] While the ability to organize information in this manner is relatively new, arising as it does from recent technological advances, the concept has longer historical roots. In 1945, Vannevar Bush, the science advisor to President Roosevelt, criticized the artificiality of the information indexing systems of the time. Noting that information was often stored either alphabetically or numerically in a series of subclasses, Bush commented that

> The human mind does not work that way. It operates by association. With one item in its grasp, it snaps instantly to the next that is suggested by the association of thoughts, in accordance with some intricate web of trails carried by the cells of the brain.[19]

The associative nature of the brain has since been observed in many contexts, and has been formalized in several models of human memory.[20] While it can be argued that the organization of information in a hierarchical or relational database can reflect important associations, such organization is often lacks the rich network of interrelationships that underlies the information. Much of this richness is lost when information is decomposed into the isolated records common to current methods of data storage.[21]

The organization and display of associated information from multiple media can be implemented using the computer technology known as *hypermedia*. The term "hypermedia" comes from a combination of the prefix "hyper," used by mathematicians and scientists to describe "extended and generalized,"[22] and "media," a common term applied to various methods of information presentation. The word itself is derived from Nelson's concept of "hypertext," which describes nonsequential writing and perusal.[23] In 1971 Nelson extended the concept of hypertext to include other forms of media, including graphics and moving images. Hence the term hypermedia was coined to describe the concept of organizing and presenting associated information in a manner, sequence, and depth of detail that best suits the user's needs.

Hypermedia Structure. Hypermedia systems are often confused with databases. The primary difference between the two lies in the way their information is organized. While a hypermedia system may act like a database at times, its capabilities are more profound. In explaining this difference a useful analogy is the difference between an encyclopedia and dictionary. Databases work like a dictionary in the way they allow the user to retrieve specific information pertaining to a particular case. For example, a dictionary offers access to information defining the term "automobile," including explanations of how the word is used in the English language. An encyclopedia, on the other hand, offers not only a literal definition (description) of the automobile, but information about its history, the manufacturing industry, mechanical and electrical systems, safety, insurance, etc. Furthermore, a good encyclopedia will include cross-referenced topics (e.g., the automobile's effect on urban growth) and bibliographic references. Due to the limitations of paper documents, the encyclopedia user may have to turn to another volume to follow a cross reference. In an analogous hypermedia system, however, the user may need only click a mouse pointer on a cross-reference listing to open a rich new domain of associated information. Clicking on "urban growth," for example, the user may be given the opportunity to view maps showing how traffic patterns have influenced the location of business districts, the text of typical city ordinances regulating the layout of "drive-up" restaurant facilities, or photographs of inner city neighborhoods abandoned for the suburbs by middle class families. Hypermedia not only makes these domains of information more accessible than they are in hardcopy, but also offers the information in a variety of media. Although the tech-

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[18] K. Parsaye et al.
[19] V. Bush, "As We May Think," *Atlantic Monthly* (July 1945), pp 101-108.
[20] A.M. Collins and E.F. Loftus, pp 407-428.
[21] K. Parsaye et al.
[22] M. Fraase, *Macintosh Hypermedia: Vol I–Reference Guide* (Scott, Foresman, 1989).
[23] T.H. Nelson, "The Hypertext," *Proceedings of the World Documentation Federation* (1965).

nology is still in its infancy, it is already possible to integrate virtually any kind of textual, visual, and audio information into a hypermedia system. The real challenge of implementing hypermedia applications is in the structuring of the system and the organizing of the information. The advantage of hypermedia is in its *associative* structure and organization.

To more fully understand the way in which information is organized within a hypermedia system, it is useful to review the way information is organized in the two basic kinds of standard databases: hierarchial and relational.

Hierarchical databases use the concept of information hierarchy to link entities with the use of a tree structure.[24] Records of various levels are related by "owning" or "belonging to" each other. As illustrated in Figure 3, each element can carry with it an address of two or more other elements rather than just one. Hierarchical databases are most useful when the information they contain is inherently hierarchical.

The hierarchical database structure is often compared to an inverted tree. In such a structure, nodes are connected by branches with the following restrictions: (1) there is a principal node known as the "root" or "home" node, and (2) the tree branches downward from the root, with each node capable of branching into several nodes on the next level down. As a result, each node is connected to only one node above it.

Hierarchies fall into two basic categories: simple trees and those that contain "virtual record types."[25] In a simple hierarchical structure, every node is connected upwards to only one node in the tree. When many items fall under the same tree, it is sometimes necessary to break them into a "forest" of smaller trees. Virtual record types allow the user to jump from one tree to the next, as is illustrated in Figure 4 at node ">." These pointers can be either unidirectional or bidirectional. While the unidirectional logical relationship in Figure 4 allows a one-way flow between trees, the bidirectional logical relationships in Figure 5 offer the ability to move back and forth among trees.

In contrast to hierarchical databases, *relational databases* organize information so data items in one type of record may refer to records of a different type. Figure 6 shows how a relational database gives

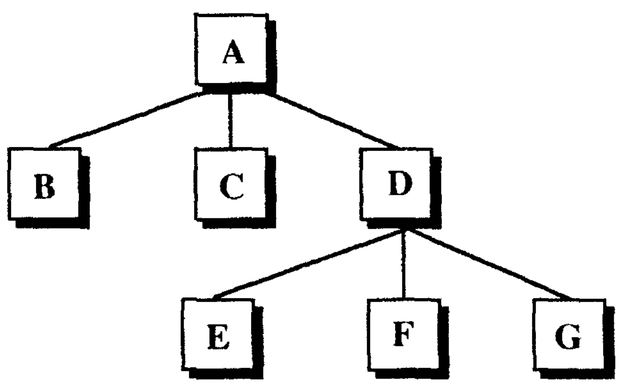

Figure 3. Simple Hierarchical Database Structure.

[24] M.L Gillenson, *Database* (Wiley, 1985); J.D. Ullman, *Principles of Database Systems* (Computer Science Press, 1982).
[25] J.D. Ullman.

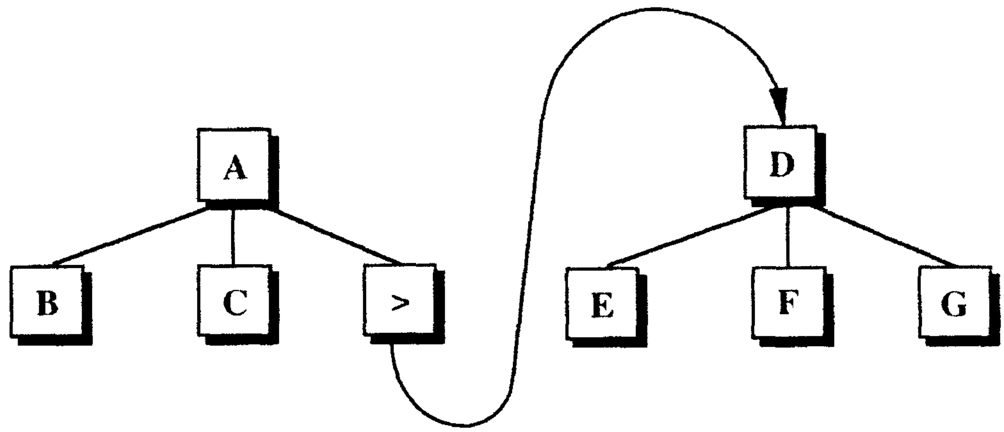

Figure 4. Unidirectional Hierarchical Database Structure.

the user the flexibility to join or link information stored in many files. Information can be interchanged and cross referenced between two different types of records. For example, products in a group of invoices can be compared to an inventory. Relational databases rely on common attributes, known as "keys," to link these separate entities. The four databases shown in Figure 6 could, for example, be an employee database, a project database, a suggestion program database, and a property database. The key that links all of these databases relationally is the employee social security number. The white bar might show employee time records, projects the employee works on, suggestions the employee has submitted, and company property signed out to the employee. Relational databases are best suited to data that must be understood through underlying parameters common across a number of tables that are not otherwise explicitly linked.

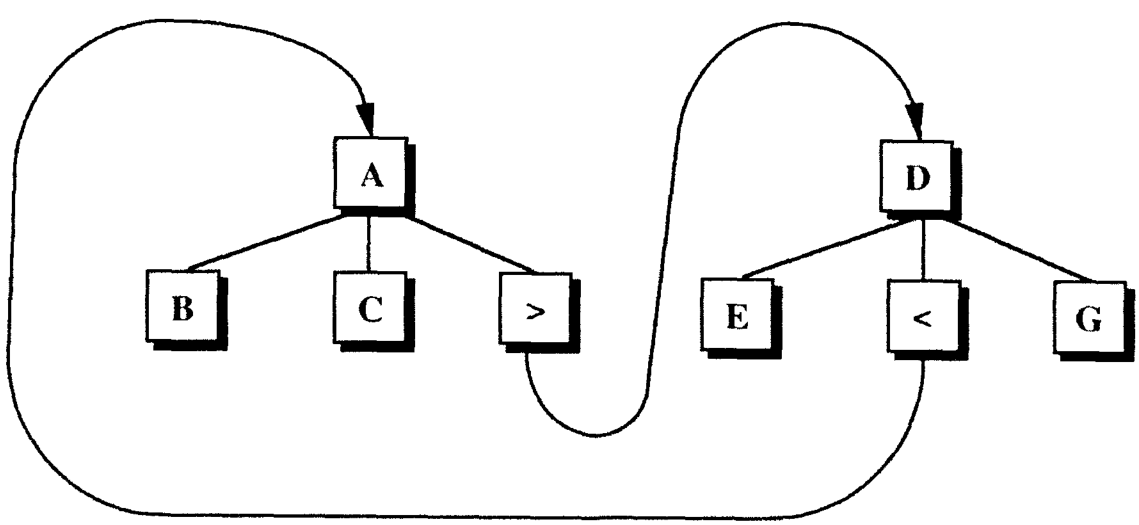

Figure 5. Bidirectional Hierarchical Database Structure.

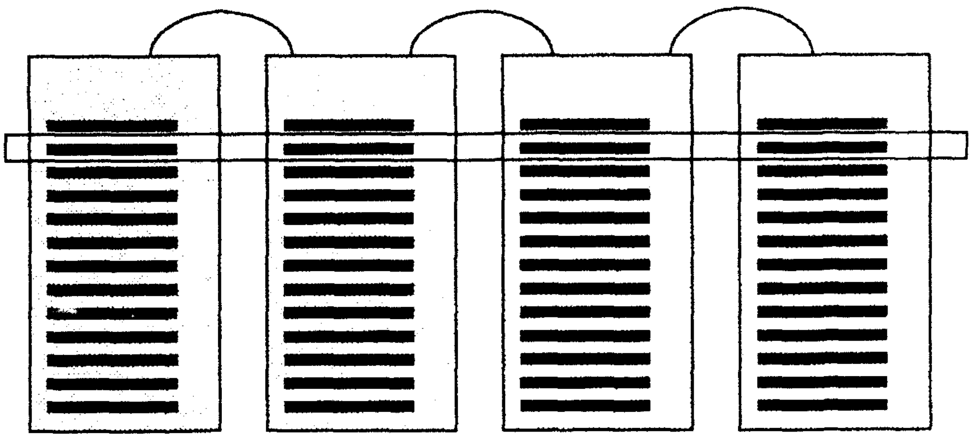

Figure 6. Four Databases in a Relational Structure.

While a hypermedia system is similar to a relational database in that it can be used to link related data, it does not require common data pointers or keys. Likewise, hypermedia can mimic the "tree" structure of a hierarchical database, but is not limited by the rigidity of the information structure. Hypermedia's logical information structure allows the user to identify relationships among data that may not have been previously defined, as illustrated in Figure 7. This interactive system "offers further opportunities for improving the accuracy, integration and accessibility of information."[26] The power of this type of data structure makes a hypermedia system 'greater than the sum of its parts.'

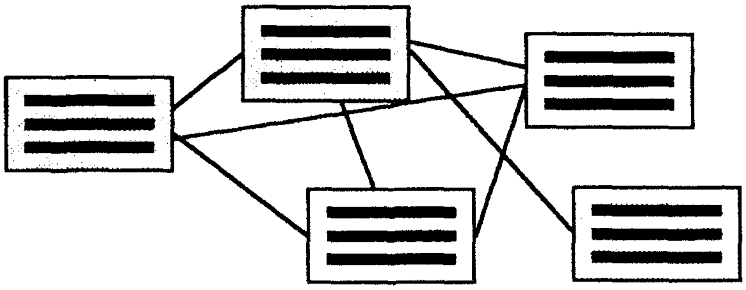

Figure 7. Hypermedia Data Structure.

[26] D.G. Lowe, "Cooperative Structuring of Information: The Representation of Reasoning and Debate," *International Journal of Man-Machine Studies*, Vol 23 (1985), pp 97-111.

At this point, it is important to draw a distinction between hypermedia and multimedia. Hypermedia refers to the associative organizational structure behind the information. Multimedia refers simply to the display of such information. It does not provide any underlying organizational structure. Interactive multimedia, on the other hand, allows the user to navigate among information in various media, but lacks the richness of a hypermedia system's underlying structure due to the user's inability to create links.

Hypermedia Uses. With hypermedia technology, Army installation planners can combine numerous information sources and formats into a resource that allows the fast cross referencing of a wide variety of concepts. This allows planning-related information, such as maps, text, statistical data, sounds, and video clips, to be organized by association much the way it is in the human mind.

The most distinctive attribute of hypermedia is the ability to trigger the recollection of associated concepts with the aid of the computer. It is important to note that this is a reciprocal process that may be advanced by both the system and the user. On the one hand, the computer can help the user identify associations by exposing him or her to various stimuli. On the other hand, the user can identify associations for the computer, thereby enriching the knowledge base for future users. Therefore, the associative chain evolves in both the computer and the user.

The associative process usually begins with the user identifying links in the initial data. This may be a simple association such as that of a site description with a location on a map. The computer then identifies this information for future users who run across the data, thereby helping the user associate the two elements of information. The user, on the other hand, may be carrying information about an issue related to a particular element in the site description. He or she can then associate this information with the site description, thereby identifying another association for the computer and, more importantly, for future users.

Furthermore, rather than presenting the user with a sequence of questions that determine associations through the application of a rule structure, as is the case with many expert systems and other forms of artificial intelligence, a hypermedia system allows users to control their own navigation through the information base. This is accomplished by presenting the user with a series of crossroads or nodes via which the user is free to explore the alternatives presented.

Computer-Supported Collaborative Work

Another technological trend that complements the idea of integrating information, tools, and communication has been the movement away from individual work using computers to that of computers used in networks. Communication often dominates in collaborative meeting environments at the expense of access to information and analytical tools. Other difficulties related to the individual focus of most planning tools restrict the communication itself, as discussed at the beginning of this chapter. Computer-supported collaborative work addresses these problems by putting computer-oriented tools into meeting environments. Computer-supported collaborative work involves much more than simply the sharing of information that is made possible in conventional networks: the presence of the tools it provides may be physical, as in small group meetings; distributed, as in local area networks; or virtual, as in the "meeting rooms" found on electronic bulletin board services (BBSs).

Lowe addressed computer-supported collaborative work as it applies to conceptual meeting environments when he envisioned a system that would be able to "encode knowledge in the argument structures themselves."[27] Such a system would be similar in concept to restroom graffiti or electronic

[27] D.G. Lowe.

bulletin board services, where an idea or comment by one person is followed by others and so on. Thus, the line of reasoning in an argument could be traced along an associate chain. Lowe further noted that "this use of an interactive system offers further opportunities for improving the accuracy, integration and accessibility of information." Lowe's method is based on the use of a structured representation for reasoning and debate in which conclusions are justified or negated by individual items of evidence. "Through debates on the accuracy of information and on aspects of the structures themselves, a large number of users can co-operatively rank all available items of information in terms of significance and relevance to each topic."[28]

Computer-supported collaborative work also applies to physical meeting environments, where a group of people may have individual terminals or a shared display. For example, the development of the Colab environment at the Xerox* Palo Alto Research Center (PARC) represents an attempt to demonstrate the collaborative capabilities of computers using a prototype meeting room.[29] One research effort in the Colab environment uses two software packages designed to support work in groups distributed over a local area network (LAN). This LAN consists of five computer terminals—four for individual use and one whose display is projected onto a common screen. The software packages are Cognoter, a tool used to prepare presentations collectively, and Argnoter, a tool being developed for the presentation and evaluation of proposals.

The Cognoter organizes a meeting into three phases: brainstorming, organizing, and evaluating. Each phase adds capabilities to the previous one so that all of the activities available in the brainstorming phase can be accessed in the organizing phase, and so on. Groups that feel constrained by the enforcement of phases can skip directly to the last phase, where all operations are possible.

The brainstorming phase begins with a "clean slate" and involves the initial generation of ideas. This is accomplished by allowing participants to type words or phrases characterizing ideas that are displayed on separate terminals as well as the large screen. To reduce the inhibitions of participants, no elimination of ideas occurs during brainstorming. In the organizing phase, the group attempts to establish an order to the ideas by linking related ideas and organizing them into subgroups graphically. This process is often accompanied by a discussion of how and why ideas may be related. In the third phase, evaluating, participants review the overall structure to reorganize ideas, fill in missing details, and eliminate ideas that may be irrelevant. Irrelevant ideas identified in this phase will often be those that were not linked to others during the organizing phase. From this structure, an outline of a presentation emerges as the product of the Cognoter.

The major working hypothesis put forth by Stefik et al in the design of the Argnoter is the assertion that "making the structure of arguments explicit facilitates consensus by reducing disagreement that arises from uncommunicable differences."[30] Like the Cognoter, the Argnoter consists of three phases built upon each other: proposing, arguing, and evaluating.

In Argnoter's proposing phase, a short text description of a proposal, perhaps accompanied by a sketch, is presented in a window on the computer screen. The next phase, arguing, involves presenting reasons for choosing or not choosing individual proposals. Each statement is identified as either pro or

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[28] D.G. Lowe.

* This report necessarily uses the trade names of many commercial companies and products. These trade names are trademarks or registered trademarks of their respective owners.

[29] M. Stefik, G. Foster, D. Bobrow, K. Kahn, S. Lanning, and L. Suchman, "Beyond the Chalkboard: Computer Support for Collaboration and Problem Solving in Meetings," I. Greif, ed, *Computer Supported Cooperative Work* (Morgan Kaufmann, 1988), pp 335-366.

[30] M. Stefik et al, p 349.

con, and consists of a short text description like "too costly," etc. Participants can also add statements or modify existing proposals at this phase. In the final phase, evaluating, the assumptions behind individual arguments are considered. These usually take the form of statements about statements. Differences or conflicting statements are mapped into "belief sets" that are then displayed in the form of an "argumentation spreadsheet," where a proposal is viewed and evaluated in relation to a specified set of beliefs and evaluative criteria. Here, one could conceivably change a belief set or the ranking of evaluative criteria and see the recommended proposal change, based on the underlying logic put forth in the arguing phase and the first part of the evaluating phase.

The Colab was not the first attempt to incorporate computers into group decisionmaking processes. In 1975, Rouse and Sheridan viewed computers as having two possible roles in group decisionmaking:

> The simpler role is that of "opinion manager," in the sense of keeping track of all individual and/or group decisions and, perhaps, reminding the participants of these decisions if they attempt to make contradictory statements later in the discussion. On a more sophisticated level, the computer could serve as a "guest expert," which could include accessing of databases, making predictions, and construction and simulation of models.[31]

The psychological benefits of collaborative interactions for meeting participants have been noted. Humans are identified as "social animals [with] face-to-face interaction, including the exchanging of job-related stories [being mentioned as] an important and usually underestimated means of gaining information."[32] In his design for "A Performing Medium for Working Group Graphics," Lakin cited evidence that having "a common display often aids face-to-face task groups." He went on to suggest that in using this, the social dynamics of the group may change for the better. "More of the group's members tend to participate in idea generation, rather than the concepts being controlled by the verbally and/or politically dominant."[33]

In Army planning, the decisionmaking rationale of planners is often subordinated to the goals of the installation commander. The ability of collaborative computer systems to enhance the decisionmaking process should not be underestimated. Better integration of the commander's goals with the recommendations of installation planners would result in better communication between the two players, and would greatly improve planning decisionmaking.

User Interface Design

A recent technological trend that complements hypermedia has been the movement from command-driven to graphical user interfaces. Prior to this development, most computer interfaces were command-driven: the user had to translate his or her intentions into commands that could be understood by the machine. Command-driven interfaces often require a large amount of memorization that is analogous with learning a new language. Unfortunately, people who could not communicate in this "language" were either completely left out of computer-aided processes or heavily reliant upon people who knew the computer's language.

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[31] W.B. Rouse and T.B. Sheridan, "Computer-Aided Group Decision Making: Theory and Practice," *Technological Forecasting and Social Change*, No. 7 (1975), pp 113-126.

[32] W.B.Rouse and N.M. Morris, "Understanding and Enhancing User Acceptance of Computer Technology," *IEEE Transactions on Systems, Man, and Cybernetics*, No. 6 (1976), pp 965-973.

[33] F. Lakin, "A Performing Medium for Working Group Graphics," *Computer-Supported Cooperative Work*, Irene Greif, ed (Morgan Kaufmann, 1988), pp 367-396.

Graphic interfaces were developed to overcome the need to memorize commands by translating the user's actions into commands that can be understood by the machine. While much of this effect can be accomplished by adding a menu structure to a user interface, the inclusion of a direct manipulation capability to a graphical interface offers a concrete framework for the user to operate within. A graphical interface is displayed in a form that matches the way the user thinks about a problem. This way the user can execute "rapid incremental reversible operations whose impact on the object of interest is immediately visible."[34] An example of this is the input of values through the use of sliding bars that immediately interact with an algorithm which, in turn, displays a graphic image on the computer screen to represent the output. Thus, rather than implementing analytical models by typing codes or numbers, planners can point to maps and photos, slide levers and push buttons using a direct manipulation interface to elicit a response from the computer. The benefits of graphic interfaces in decision support systems are supported by psychological evidence. According to Woods, for example, "the graphic knowledge system concept for decision support is based most simply on the empirical finding that vision enhances human problem solving."[35]

Graphical interfaces can make the output characteristics of a computer more readily understandable by users. This involves designing the displays to present information in a manner that allows for "pleasurable engagement," with an interface so engaging that the machine essentially becomes "transparent" to the user.[36] The user readily interacts with the information without becoming distracted by the delivery mechanism. In this way, users become so engaged in working with the information that they forget that they are using a computer.

Pleasurable engagement involves incorporating concepts such as "visual presence" and "multiple representations." Visual presence aids in evaluation by providing visual reminders of what was done. For example, grayed-out text can be used to signify portions of a plan that were already read or alternatives recently selected. In addition to this, visual presence can aid in interpretation through the enhanced display of text, graphs, moving images, and pictures.[37] Multiple representations of a problem[38] enable the user to view information in several different contexts, offering the potential to generate alternative approaches to a problem. An example of this would be highlighting the impact of a proposed transit station on a surrounding neighborhood using a graph in one window to display the change in land values, another window to reflect shifts in demographics, and a video record running in a separate window or on a separate monitor to display physical changes.

Thus, in the computer-aided decisionmaking environment, the user must develop understandings and representations of a problem as it is represented in the decision support system. This can be done by using interface techniques known as representation aids.[39] Representation aids are designed to allow the user to interact with the decisionaiding algorithms as naturally as possible. This minimizes the cognitive load that can be imposed by the decision aid since it reduces the need for the user to translate his or her ideas into information understandable by the computer (and vice-versa). Representation aids

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[34] E.L. Hutchins, J.D. Hollan, and D.A. Norman, "Direct Manipulation Interfaces," *User Centered System Design: New Perspectives on Human Computer Interaction*, D.A. Norman and S.W. Draper, eds (Lawrence Erlbaum, 1986), pp 87-124.

[35] D.D. Woods.

[36] B. Laurel, "Interface as Mimesis," *User Centered System Design: New Perspectives on Human-Computer Interaction*, D.A. Norman and S.W. Draper, eds (Lawrence Erlbaum, 1986).

[37] D.A. Norman, "Cognitive Engineering," *User Centered System Design: New Perspectives on Human Computer Interaction*, D.A. Norman and S.W. Draper, eds (Lawrence Erlbaum, 1986), pp 31-61.

[38] J. Rasmussen, *Information Processing and Human Machine Interaction: An Approach to Cognitive Engineering* (North Holland, 1986).

[39] W. Zachary, "A Cognitively Based Functional Taxonomy of Decision Support Techniques," *Human-Computer Interaction*, Vol 2 (1986), pp 25-63.

accomplish this by using graphics in both the reporting (output) of information and the input of information.

Representation aids also allow the user to represent a problem in a way that takes advantage of a special cognitive processing ability, such as the parallel processing capability inherent in visual perception. This can be accomplished by providing both pictures and text for conveying information so as to pleasurably engage the user. Finally, representation aids are designed to enable the capture of an expert's representation of a problem and incorporate it into the interface as an aid to novice users. The use of multiple media allows the expert's representation of a problem to be captured more faithfully than the use of a single medium (such as text) would allow.

3 THE DEVELOPMENT OF A HYPERMEDIA-ASSISTED PLANNING SYSTEM

A Hypermedia-Assisted Planning System (HAPS) is a means to effectively integrate the planning activities of communication, information access, and the use of analytical tools. Recent advances in technology now make the development of an effective HAPS possible. Such a system could take advantage of direct manipulation graphic interfaces, associative information structuring, and group decisionmaking. By implementing such a system, planners will be able to take a more holistic approach to planning. This could lead to the development of a greater range of alternatives, improved communication, and better planning decisions.

The three components of a collaborative planning process can be integrated with recent technological advances into a HAPS, as illustrated in Figure 8. The planner can use the HAPS as a toolbox to access various models for forecasting and performing general *what-if* analyses.

The hypermedia component of a HAPS can more accurately illustrate urban or installation relationships than standard systems (spreadsheets, databases, etc.) because of its ability to mix spatial, political, economic, and other related information through the use of sound, graphics, video, animation, and text. By providing multiple representations of a problem,[40] HAPS enables the user to view the information in several different contexts, offering the potential to generate alternative approaches to a problem by viewing the information from a different viewpoint.

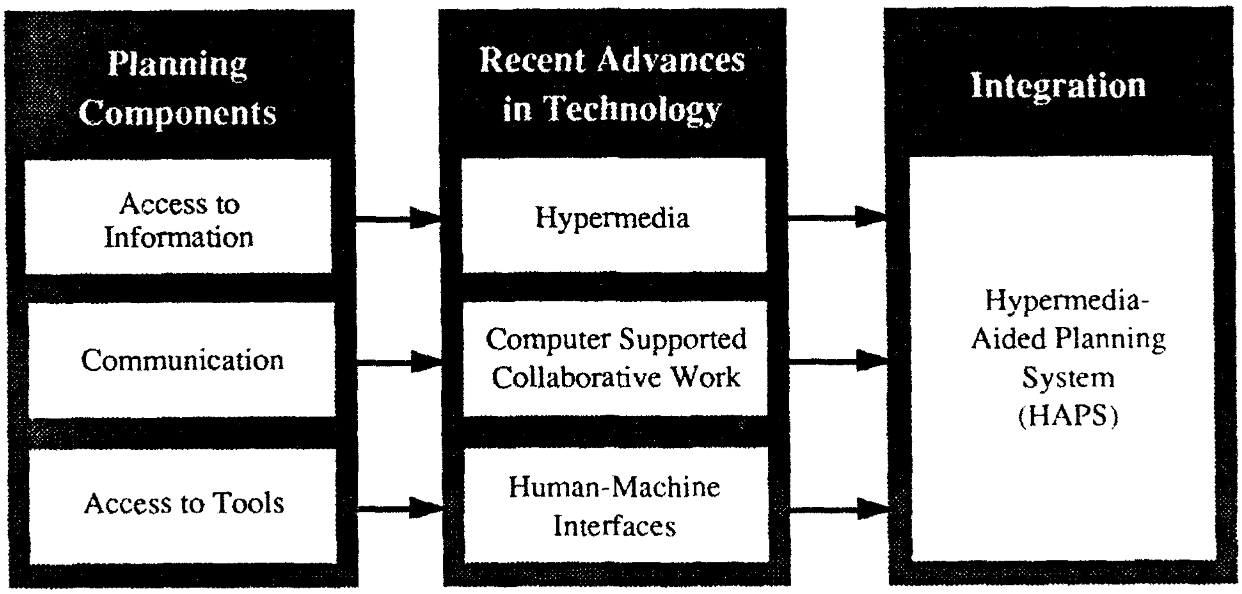

Figure 8. Integration of Planning Processes and Hypermedia Technology Into a HAPS.

[40] J. Rasmussen.

By exploring a hypermedia system consisting of information added over a number of years, users can identify relationships to create links and append information. It is possible to have input not only from all those present at a particular meeting, but also from anyone who has interacted with the system since its development. Thus, HAPS stresses a participative form of information organization with an emphasis on the idea of people working collaboratively even across time.

System Development

The development of a hypermedia system must be individualized to meet the specific needs of the installation developing the system. Figure 9 illustrates a variety of components that can be added to a basic hypermedia system. The components added will be based on the type of information used and budgetary constraints. Because of these variables, hypermedia components will be discussed for two development platforms—the Apple Macintosh and the IBM PS/2—and for both high-end and low-end theoretical configurations.

The implementation of a hypermedia system typically begins with a definition of the problem area and the initial collection of information. While it would be ideal to anticipate all of the system's information needs and collect the necessary data initially, experience has shown that this is not practical nor possible. This is because development time usually is limited and it is difficult to accurately anticipate a system's future information needs. The method of system development proposed here considers those limitations. It must be cautioned, however, that these recommendations are application-dependent; and it may be necessary to modify this process when confronted with a unique situation.

The initial information to be collected will typically consist of existing maps of various scales and visual images of selected sites. The scale of the maps depends on the project scope and the amount of information available for each area. These maps can be adapted from existing CAD files or scanned in

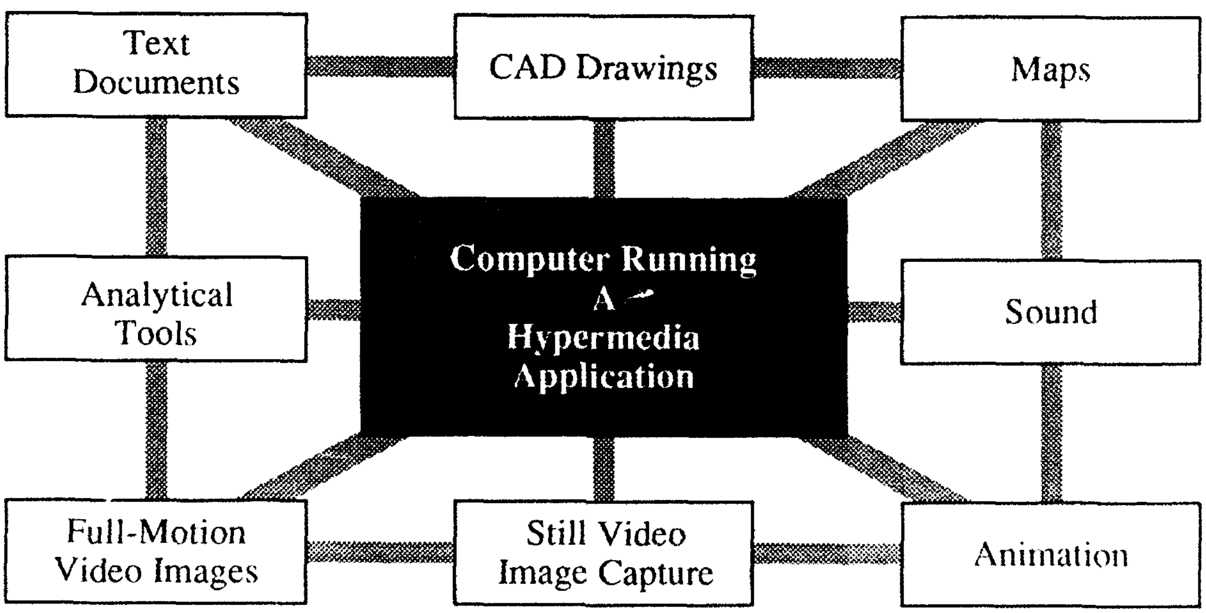

Figure 9. A Basic Hypermedia System With Possible Components.

from hard copies. Images of specific focus areas are then collected to help visually familiarize the users of the system with the locations of interest. These images can be in the form of slides, photographs, or videotape that are then scanned into the computer and linked electronically to the maps. For an Army installation, the principal map might be the base installation map, linked to more detailed maps that can be examined at a larger scale.

The purpose for building the image base first is to enable the system's use at initial planning meetings during which planners often examine maps and try to visualize current conditions. At this point in the HAPS development, the work group could meet with the system projected on a screen and determine the areas for which more information is needed in the system to make it more useful. It can be expected that additional visual images, as well as site descriptions, drawings, sounds, and possibly video interviews with associated individuals, would be specified for further collection. It is at this point that the users actively shape the system by adding information to suit their needs. For an Army installation planning group, it may be decided that the next step is to link building floor plans to appropriate locations on the map. Figure 10 shows other activities that could become part of the HAPS for an installation.

The system's refinement process involves adding elements of information in an iterative manner. User suggestions for system revisions are evaluated on the basis of their applicability to the system and the planning process. If it is determined that a proposed change would not adversely affect other components of the system or user interaction with the system, then the suggested revisions are incorporated.

Revisions can be incorporated by whatever methods best suit the task at hand. For example, if comments call for the inclusion of an additional analytical model, a module (in the form of an additional window) may be created using object-oriented programming techniques and tested for compatibility with the rest of the system. If the new module works, it is implemented. If the new module is incompatible with the rest of the system, it is revised and retested before inclusion.

The following sections outline some of the hardware and software options available to developers of hypermedia systems. Because microcomputer technology changes and evolves so rapidly, the following information should be considered representative rather than definitive.

Hardware Requirements and Options

The display requirements of a HAPS are directly related to the number of participants in the work group. A video projector is required if the system is to be used by more than five or six individuals at one time. Smaller groups can use a high-resolution color graphics monitor, with a second monitor for displaying video output from a laserdisc or videocassette recorder.

In addition to the system's display requirements, a central processing unit (CPU), input devices, and appropriate peripheral devices are also necessary. Initially, at least two pointing devices—mice—and one keyboard are necessary to allow participants to interact with the system. Extension cables are recommended so pointing devices can be easily passed between participants during the planning sessions. Ultimately, in a fully integrated system, each participant should be provided the means to individually interact with the system.

The ability to capture and display video images on a color monitor requires a video "frame-grabbing" device. The ability to overlay computer graphics and animations onto motion video for visualization purposes requires the use of a video overlay board. Other peripherals that may be useful include a high-resolution video camcorder for the capture of highly detailed video images, a computer-controlled videotape or CD-ROM drive for random access to video images, a sound digitization device

TYPICAL INSTALLATION PLANNING ACTIVITIES	HYPERMEDIA SYSTEM CAPABILITIES									
	Text Documents	CAD Drawings	Scanned Images	Sound	Animation	Still Video Images	Full Motion Video Images	Analytic Tools	Extenal Info Access	Spreadsheets
MP Map Updates		●	●							
Site Planning	●	●	●			●			●	●
Site Selection	●	●	●			●	●	●	●	
Consult Regulations	●								●	
BRAC Activities	●	●	●		●	●	●	●	●	●
1391 Preparation	●	●	●						●	
Stationing Excercises	●	●	●		●			●	●	●
IDG Consulting	●	●	●	●		●	●		●	
TABs of Existing Facilities	●							○	○	○
Presentations	●	●	●	●	●	●	●		○	
What-if? Scenarios	●	●	●	●	●	●	●	○	○	○
Environmental Coordination	●	●	●			●	●		○	
Carrying Capacity Analysis	●	●	●		●	●	●	○	○	○

Figure 10. Applicability of Hypermedia to Typical Installation Planning Activities.

for the capture of audio information, and a large-scale storage device (such as a magneto-optical drive or high-capacity hard disk) for the storage of captured information.

The specific combination of the hardware and software necessary for a HAPS will vary depending on the planning team's objectives. Hypermedia applications are available for a number of platforms, but this report addresses two common microcomputer environments that employ graphical user interfaces: the Apple Macintosh and IBM-compatible DOS/Windows* systems.

A low-end hardware configuration for the Macintosh might include:

- Mac Classic with 4 megabytes (MBs) of random access memory (RAM)
- 40 MB hard disk.

A useful high-end Macintosh hardware configuration might include:

- Mac Quadra 950 with 32 MB RAM
- 320 MB hard disk
- Two-page high-resolution color monitor (1280 x 1024 pixels)
- Sound input device
- Video overlay boards (frame-grabber and full-motion video)
- Video storage device
- Postscript laser printer or plotter.

A low-end IBM DOS/Window-compatible hypermedia hardware configuration might include:

- 386/16 CPU with 4 MB RAM
- 60 MB hard disk
- Color monitor.

A high-end IBM DOS/Window-compatible hardware configuration could include:

- 486/33 CPU with 16 MB RAM
- 300 MB hard disk
- Color monitor
- Video overlay board
- Audio digitizing card
- Video storage device
- Laser print or plotter

Software Requirements and Options

The software required for a HAPS includes several programming environments for original development work. Also, several stand-alone applications may be required to complete the system.

* DOS is Disk Operating System; Windows is a software product by Microsoft Corp. that overlays a graphical interface onto DOS and Windows-dependent applications.

The basic software required for a low-end Macintosh system would include:

- Hypercard
  - Bundled with all Macintosh CPUs
  - Provides hypertext/hypermedia programming capabilities
  - Can support black and white text and graphics
  - Can import and export information
  - Can provide data management capabilities
  - Sound support
  - Video image accessing capabilities.

High-end Macintosh hypermedia applications include:

- Supercard
  - Provides hypertext/hypermedia programming capabilities
  - Can support color text and graphics
  - Can import and export information
  - Can provide data management capabilities
  - Sound support
  - Video image accessing capabilities.

- MacroMind Director
  - Animation and story creation capabilities
  - Effective for preparing public presentations
  - Effective for preparing training visuals
  - Can support color text and graphics
  - Video capture support
  - Image editing, drawing, and colorization
  - Sound digitizing, editing, and mixing
  - Video image accessing capabilities
  - Can export information to videotape.

Low-end software for a DOS/Windows configuration might include:

- Linkway
  - Provides hypertext programming capabilities
  - Speech adaptor support
  - M-motion adaptor support
  - AVC support.

- Tool Book
  - Provides hypertext/hypermedia programming capabilities
  - Can support color text, graphics, and Windows 3.X
  - Can import and export information
  - Can provide data management capabilities.

High-end hypermedia software for a DOS/Windows configuration might include:

- Audio Visual Connection
  - Provides hypermedia programming capabilities
  - Effective for preparing public presentations
  - Can support color text and graphics
  - Video capture support
  - Image editing, drawing, and colorization
  - Sound digitizing, editing, and mixing support
  - Video image accessing capabilities.
- Ten Core
  - Animation and story creation capabilities
  - Effective for preparing training visuals
  - Can support color text and graphics
  - Can use sound card
  - Can export information to videotape.
- StoryBoard Plus
  - Animation and story creation capabilities
  - Effective for preparing public presentations
  - Can support color text and graphics
  - Video capture support
  - Drawing capabilities
  - Sound card support.

A Prototype HAPS

To test the suitability of hypermedia technology and system development methods when applied to the planning process, a prototype HAPS has been constructed. The prototype system contains many elements likely to be found in future versions of such systems. The HAPS prototype attempts to address problems such as multimedia information overload, the highly technical nature of current planning tools, and the need for interaction among members of the work group. Specifically, this prototype is able to (1) organize and display information from a variety of media in an associative form, (2) provide an intuitive graphical interface to make planning tools more accessible, and (3) support decisionmaking in a group environment.

Without respect to the particular platform or specific hardware and software employed, the HAPS prototype design consists of three functional components:

1. A multimedia information base that brings together quantitative and qualitative information on a wide variety of subjects

2. A creation mechanism that supports the initial generation of ideas using an on-screen electronic "sketchpad," where sounds, images, and text can be generated by users or retrieved from the information base and grouped into associative structures

3. An external communication mechanism that provides a facility for the preparation of presentations using printed reports, drawings, videotape, and photographic slides.

These three components can be used alone or in conjunction with other components, in either a group or individual decisionmaking environment.

The Information Base

The information base of the HAPS prototype brings together quantitative and qualitative information on a wide variety of subjects using multiple media. The prototype is capable of using maps, statistics, text, and video to store environmental, economic, land use, and other related information about a geographic area. The maps and video image are dynamically linked to the information base; by simply requesting this information via a mouse click or keyboard command, the user can highlight a site's geographic location as well as its appearance.

Using the textbook as a model (or "metaphor"), the information base organizes areas of interest in the form of "chapters." This type of organization minimizes the disorientation that can occur when navigating through a large hypermedia system. These chapters are presented as a series of windows displayed on a monitor. Within each chapter is a number of "pages," each of which contain a unit of information. This information unit often consists of a written description of an area of interest. Each page also contains reference materials, such as pertinent addresses, contacts, and the source of the information unit. These reference materials are accessed by using the system's mouse to point at a graphic symbol, or "icon," and activate the information it represents by "clicking" a button.

In this prototype system the user can obtain information by (1) searching for subjects or key words using the system's menu structure, (2) searching geographic areas for information by pointing to an area of an on-screen map and clicking a mouse button, and (3) navigating around a site using on-screen video information. Each of these procedures can yield associated information "cards," a video image, or an automated map.

One use planners will have for this type of system is as an aid in writing reports. For this, the planner may access the information base while compiling a report. Relevant graphics and passages of text on a variety of topics can be electronically copied from the information base and pasted directly into the report. Planners may also use the system for browsing individually or in groups, during brainstorming sessions, for example, where members of the work group can prepare for a session by familiarizing themselves with a particular area or areas.

Although the HAPS information base offers many benefits, it may also present some difficulties. The most challenging task in the operation of any hypermedia information system is information verification and updating. Since the quality of the information base directly depends on the information it contains, procedures must be established to verify information before it is added to the system. A system that is not regularly updated loses its effectiveness. Currently, information verification in the HAPS prototype occurs during the information collection phase of system development. Because of the system's organization into chapters, specific units of information can be quickly accessed for updating. Updating in the prototype HAPS occurs at the time new information becomes available.

Creation Mechanism

The system's creation mechanism supports the generation of ideas using a multimedia "brainstorming" component. As mentioned earlier, the interface of this component is based on the idea of an on-screen electronic "sketchpad" by which the user may control sounds, images, and text. Also,

nodes of relevant information can be retrieved from the information base and grouped into associative structures for the identification of issues, problem areas, or strategies.

The information nodes can be used to visualize a single complex issue or a set of software issues. Often, as a group of issues is identified it will become apparent that some are interconnected. Thus, it is best to explore the issues jointly rather than one at a time. The identification of linkages can be symbolized by graphically drawing a line that links them electronically and visually. At this point in the meeting it may be necessary to take a conceptual step back and view the problem graphically (Figure 11). From this, a number of areas to focus on may become apparent to meeting participants. Thus, a wide range of issues can be considered initially and narrowed later into more specific focus areas.

The ability to teach the system to make associations is a strong feature of the creation mechanism. This teaching process makes use of the parallel distributed processing (PDP) approach to finding implicit links in information.[41] The PDP approach involves identifying the components of ideas, plans, or designs as generic concepts that can be incorporated in the development of alternative solutions to planning and design problems. There can be a variety of relationships between these components, including being "dependent on," "kind of," "part of," or a "sibling of" another chunk of related information. This kind of knowledge representation is known as a schema. A schema is described as a data structure for representing generic concepts stored in memory. By developing various schemata, one can add a kind of "intelligence" to the information used in decisionmaking. For example, the computer is taught to recognize the concept of "riverfront development." By building upon this and other references

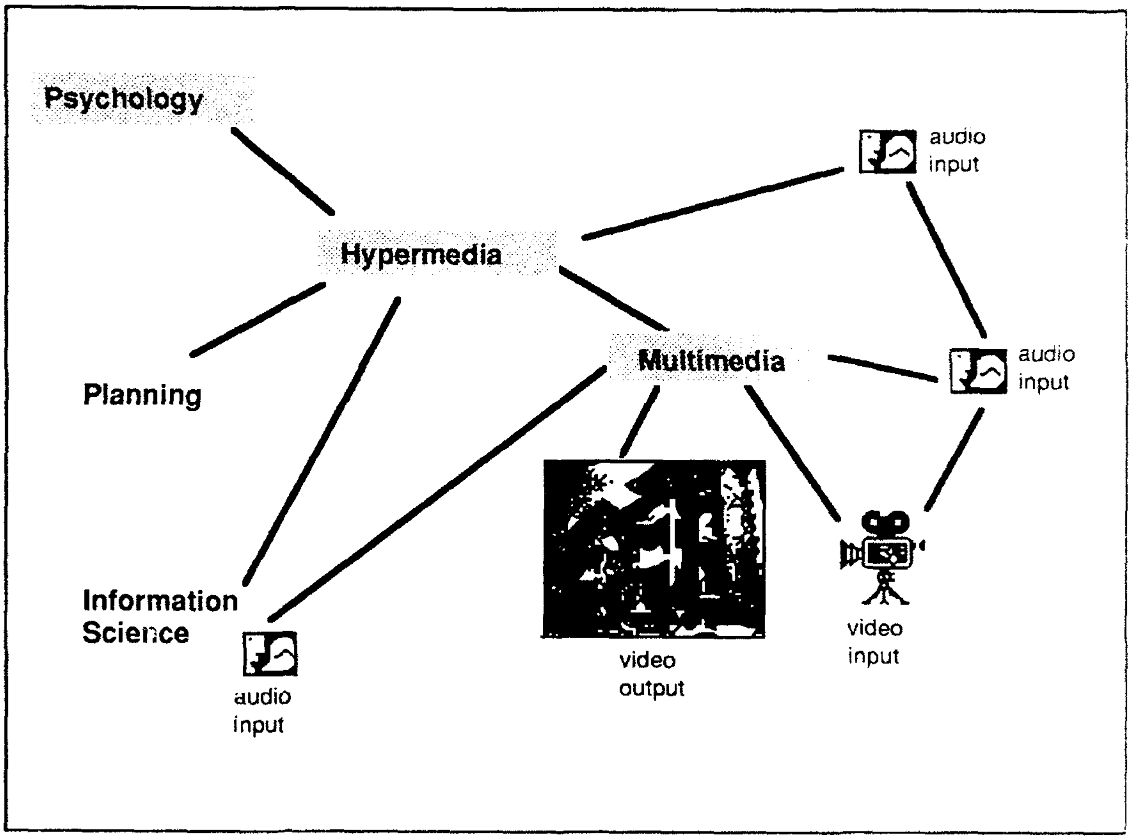

Figure 11. Example of Creation Mechanism Interface, Including Text, Graphics, Video, and Sounds.

[41] R.D. Coyne and S. Newton, "Design Reasoning by Association," *Environment and Planning B*, Vol 17 (1990), pp 39-56.

to riverfront development (e.g., water, erosion, marinas, beaches, boats), the computer builds a schema based on a general waterfront development experience. From this, associations can be made with common elements of other concepts, with the computer identifying linkages such as waterfront development-marina-entertainment-amusement park. This can be a powerful aid in the brainstorming process.

The creation mechanism also supports access to tools for linking, sketching, and sound annotation. The linking tools can be used to create buttons—visual symbols to click with the mouse—that link related information from a variety of source media, including maps, video images, text, and sounds. One can use these links to independently identify associations among the information that may have been overlooked by the computer's schemata.

The sketching tool allows a user to create color graphic overlays on maps and drawings for the purpose of highlighting areas of interest. It also supports video image processing techniques for the visualization of proposed changes to the built environment. The sound annotation tool allows one to label text, graphics, or video with sound. The tool creates an object, such as a polygon, that can store and replay any variety of sounds, such as airport noises, traffic sounds, and verbal comments. These objects can be linked to any element of the system, including the information cards, maps, aerial photos, or the electronic sketchpad.

Communication Mechanism

The purpose of the communication mechanism of the HAPS prototype is to provide a facility for the preparation of presentations. The presentation's content can be drawn from a variety of the system's sources, including the information base. Presentations can be output in a number of forms: printed reports, drawings, videotape, or slides. When projected on a screen, the system itself can be used as an interactive presentation mechanism. Using the system this way, meeting participants do not have to passively watch a linear presentation: they can also raise issues and questions that change the direction of the presentation. Due to the importance of group interaction in the planning process, this single application of the HAPS is a significant benefit to users.

The prototype HAPS also supports the generation of printed documents and limited animation capabilities that can be output to videotape. Printed documents can be compiled using a word processing package that can combine text and graphics gathered from the information base while running in a separate window on the computer screen. Simple animations can also be created and combined with video disc sequences for output to video tape. Other methods of output are possible, depending on the system configuration.

Recommendations for Implementing a Prototype HAPS

Based on the authors' combined experience in developing a prototype hypermedia system for municipal planning, knowledge of the requirements of Army installation planning, and initial research and development of HAPS technology currently in progress for the Army by USACERL, a number of recommendations are made for the benefit of installation planning teams considering the implementation of a hypermedia system.

First, it is very important that the system's objectives can be stated clearly and concisely at the outset of system development. This is critical to keep the system's development focused to meet the objective. Because of hypermedia's superior ability to form associative links across diverse information sources, there is a very real danger that the system's development may get sidetracked. This can waste time and resources by duplicating information available elsewhere or creating system modules that are unnecessary

to the system's objectives. It is important to hold frequent meetings of the system's designers, developers, builders, and end users to ensure that the objectives are clearly understood by all and that the goals are ultimately achieved.

The procedure for effectively implementing a hypermedia system to assist in Army installation planning must include the following six steps:

1. Overall system design
2. Equipment purchase
3. Information collection
4. Software development
5. Entry of relevant data
6. Initial linking of data with video images, graphics, and maps.

After studying the prototype hypermedia-based planning system developed for the City of St. Louis, MO, as well as the requirements of Army installation planning and the requirements of the planning profession in general, the authors have identified several guidelines for developing a similar system for Army use.

Limit the System Application Area

Hypermedia works best within a limited area of application. Because of the limitless potential for displaying information from multiple media, it helps to set geographical and conceptual boundaries. It is also best to define the level (or levels) of information resolution (detail) at the of outset of system development. As shown previously in Figure 10, there are more than a dozen installation-level planning activities in which a HAPS could appropriately be used at the outset, even in a conservative approach to implementation.

Use a Modular Approach to System Construction

It is best to build the system one step at a time by taking a modular approach. It is very difficult to get a hypermedia system up and running while trying to develop all aspects of the system at once. By taking a modular approach, it is easier to create a functional system in a limited period of time. Furthermore, as other modules or components are added, it is easier to determine which components will work smoothly with the system, and which will malfunction.

Allow the System To Mature

To become truly useful, a hypermedia system must age. Few hypermedia systems are very useful out of the box. The process of *aging* or *maturing* occurs as individuals interact with the system over time, adding ingredients of knowledge by building links and relationships among the data. Users add their own knowledge as they add information and draw new associations among existing information. Thus, the more people use a hypermedia system, the more knowledge is added to it, making it more useful.

Assess Effectiveness in Planning Activities

While the potential benefits of a HAPS are obvious in conceptual terms, the complexities of the system and the planning process will require the study of real-world users to fully adapt the technology to the purpose. A key area to study will be the specific impact that these systems have on the dynamics of group decisionmaking. Other aspects of installation planning will also have to be studied to optimize the use of the technology as the benefits and potential drawbacks of the HAPS are documented.

4 CONCLUSION

This report has examined the applicability of hypermedia technology to the process of planning, with a focus on the potential for developing a hypermedia-assisted planning tool for Army installation planners. The components of the planning process--technological tools, units of information, and modes of communication--were discussed, and it was shown that hypermedia offered a potential for improving the process in each area. A prototype hypermedia system for municipal planning was studied for concepts applicable to the Army installation planning environment. Possible configurations of commercially available microcomputer hardware and software were outlined to illustrate that a HAPS may be implemented for two widely used platforms. On the basis of the authors' hypermedia development experience as well as initial USACERL research and development in this area, recommendations were offered for installation planners considering the implementation of a HAPS.

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ABBREVIATIONS AND ACRONYMS

BBS	bulletin board service
CAD	computer-aided design
CD-ROM	compact disc-read-only memory
CPU	central processing unit
DOS	Disk Operating System
GIS	geographic information system
HAPS	hypermedia-assisted planning system
LAN	local area network
MB	megabyte
PARC	(Xerox) Palo Alto Research Center
PDP	parallel distributed processing
RAM	random access memory
USACERL	U.S. Army Construction Engineering Research Laboratories

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